Space Weather Technical Forecast

Issued on Thursday, 23 December 2021 at 13:16 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: Chance of G1/Minor Storm late on day 1 into day 2 (23rd/24th) with CME arrival. Chance of R1/R2 blackout with slight chance R3 blackout. Chance Active fluence day 1.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity has been moderate over the past 24 hours, with numerous C-class flares observed, with largest flare of C8.8 at 23/1808 UTC from AR2907. There are nine sunspot regions. AR2907 Eac/Beta is the most complex, and has been developing further as it approaches the southwest limb. This is followed by two further, but smaller and decaying regions AR2908 Cai/Beta 8 and AR2909 Hax/alpha. The main other flare risks are from AR2916, Eho/Beta which is a large, but stable region, and two new developing regions AR2917 Dai/Beta and AR2918 Dai/Beta in the eastern hemisphere. All other regions, AR2911 Axx/alpha, AR2912 Hrx/alpha and AR2915 Cro are small and simple.

No Earth-directed CMEs were observed in available imagery in the last 24 hours, although three are potentially on route, although confidence is very low in the latter two with only glancing impacts possible.

Solar Wind / Geomagnetic Activity: Solar winds speeds as measured by DSCOVR at L1 have been elevated and gradually declining throughout, from 560 to 510 km/s as Earth exits the recent fast wind enhancement from CH35. Although a data gap exists 22/2126-23/0310 UTC. Density was near to above average, ranging 10-16 ppcc. Interplanetary magnetic field strength (IMF), Bt has been weak throughout, below 6 nT, with the north-south component, Bz varying from -4nT to +4nT, and becoming predominately positive (northward). Phi angle has been predominantly negative (towards the Sun). Geomagnetic activity was Quiet to Unsettled (Kp 0-3).

Energetic Particles / Solar Radiation: The high energy proton flux (greater than 10 MeV) remained at background levels. The high energy electron flux (greater than 2 MeV) rose from mainly background levels to be persistently High from 23/0920 UTC, reaching 1620 pfu at 23/1130 UTC. The associated 24-hour integrated fluence remained below the Active (1e8 integrated pfu) threshold but with a gradual rising trend, reaching 5e7 by 23/0000 UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: Low to Moderate solar activity is expected to continue through the forecast period, with C-class flares expected, a chance (40%) of further M-class flares and a slight chance (10%) of an X-class. There are also a number of filaments in the southern hemisphere which, while currently stable, continue to be monitored.

Solar Wind / Geomagnetic Activity: There are three potentially Earth-directed CMEs. The first from an M-class flare from AR2908 on the 20th, expected to arrive later day 1 (23rd) or day 2 (24th). The second, much lower confidence, from either the C-flaring of AR2909 or a filament eruption shortly before in the southeast disc on the 26th. The third from the M-flare of AR2908 on the 22nd, but has yet to be fully assessed in imagery. Otherwise elevated solar winds are likely to continue easing day 1 (23rd) as CH35 effects wane before any CME arrival occurs.

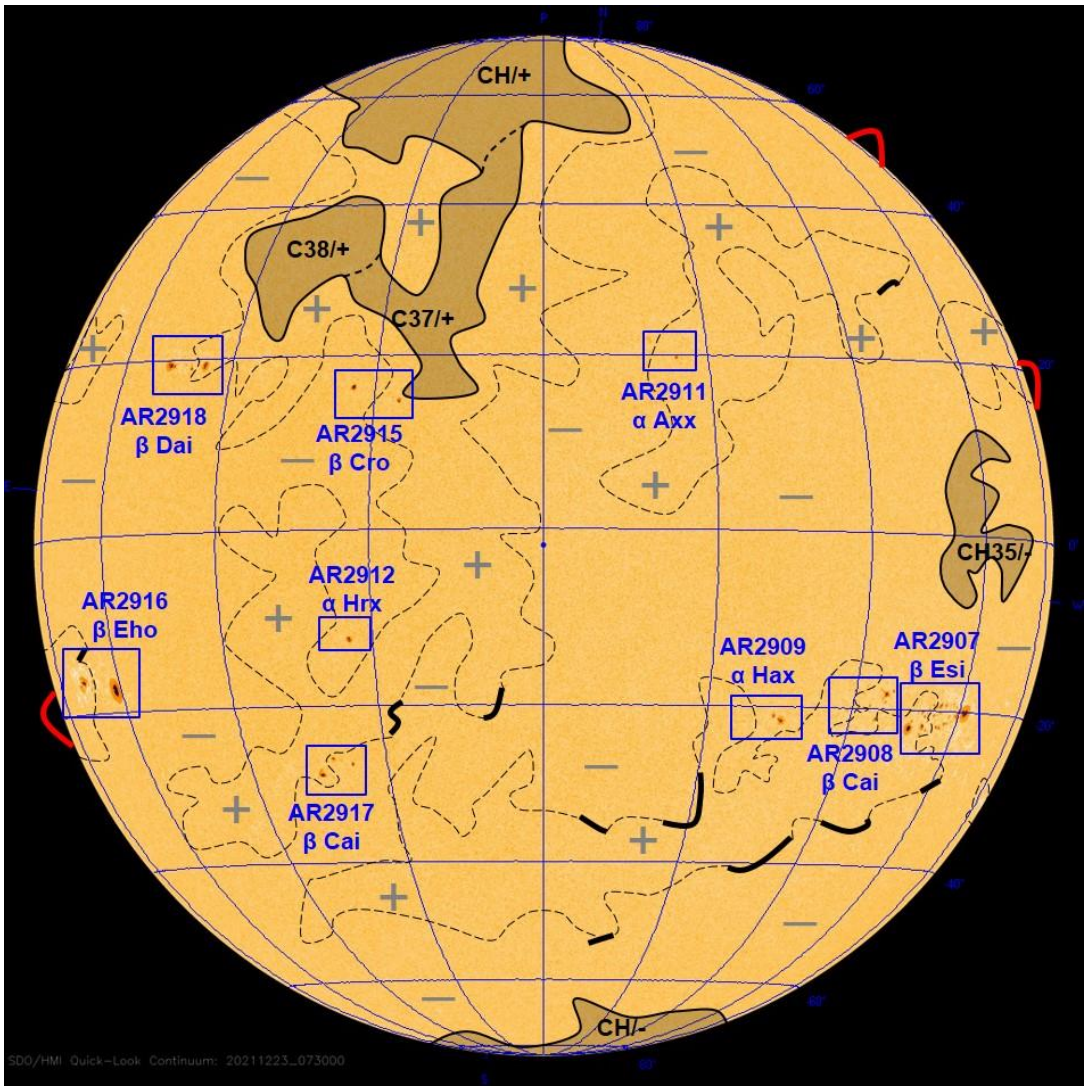
Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.

Ongoing easing of solar winds is then expected through the period once the CME has passed later day 2 (23rd). Quiet to Unsettled geomagnetic activity is generally expected with Active intervals likely in association with the CME, when there is a chance of a G1/Minor Storm. Perhaps becoming Unsettled to Active later on day 4 (26th) due to any glancing influence of the 2nd CME.

Energetic Particles / Solar Radiation: The high energy (greater than 10 MeV) proton flux is expected to remain at background levels and below the S1 level, although there is a slight chance for some increased flux from any significant flare activity. High energy electron flux has been moderate to high, and expected to persist at high day 1 (23rd) before any drop out from CME arrival. Confidence is then low beyond day 2, but further moderate to high flux is possible as fast wind and CME influence recedes. Electron fluence is likely to initially follow an increasing trend, likely becoming Active briefly day 1 and into day 2, before easing due the reduced flux levels after any CME arrival. A chance of Active levels returning by day 3, but very low confidence.

Figure 1. Solar Analysis Valid 23/0800 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.

Geomagnetic Storms:

An Earth-directed CME which left the Sun on the 20th is anticipated to glance Earth later on day 1 (23rd) or into day 2 (24th). There are two further CMEs of interest for the forecast. A CME which is visible on STEREO A, likely originating from either a filament eruption at around 21/1730 UTC in the southeast disc, or a C4 flare from AR2909 at 21/1914 UTC, or a combination of the two. A glancing influence from this CME is possible on day 4 (26th). A further very narrow CME occurred on the morning of the 22nd, perhaps associated with the M-flare of AR2908. This has yet to be fully assessed.

Otherwise solar winds are currently easing after recent prolonged enhancement due to the fast wind of CH35, and in the absence of any CME enhancement would be expected to decline towards background through the period. The next coronal hole fast wind enhancement is likely to be from CH37, a southern extension of the northern crown, most likely on day 5 (27th), but with a slight chance of an earlier arrival on day 4 (26th).

Quiet to Unsettled geomagnetic activity is generally expected through days 1 and 2 (23rd and 24th), with Active intervals likely in association with the CME, when there is a chance of a G1/Minor Storm. Geomagnetic activity is likely to become predominantly Quiet on days 3 and 4 (25th and 26th), however the is a chance of Unsettled/Active activity later on day 4 (26th) with any glancing CME impact, or if connection is made with CH37.

Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	30	20	5	10
Strong	G3	No	1	1	1	1
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

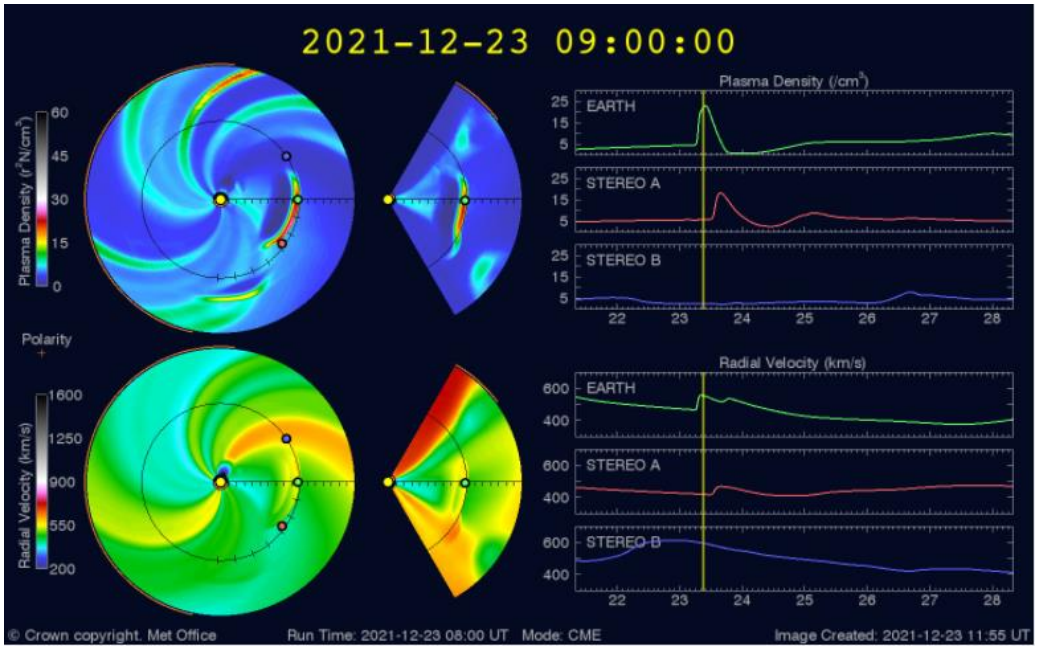
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Name	Liftoff Time	Long	Lat	Radial Speed (km/s)	Half Angle	Time at 21.5Rs
CME-202112-012	20/12/2021 12:36	11E	14S	625	34	20/12/2021 18:04
CME-202112-015	21/12/2021 19:15	30W	20S	319	22	22/12/2021 07:26

Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.

Figure 2: Enlil showing potential CME arrival. Expected later than indicated, but on the 23rd.



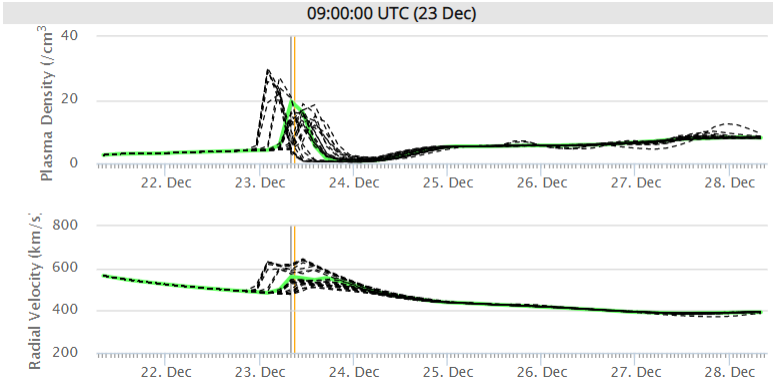
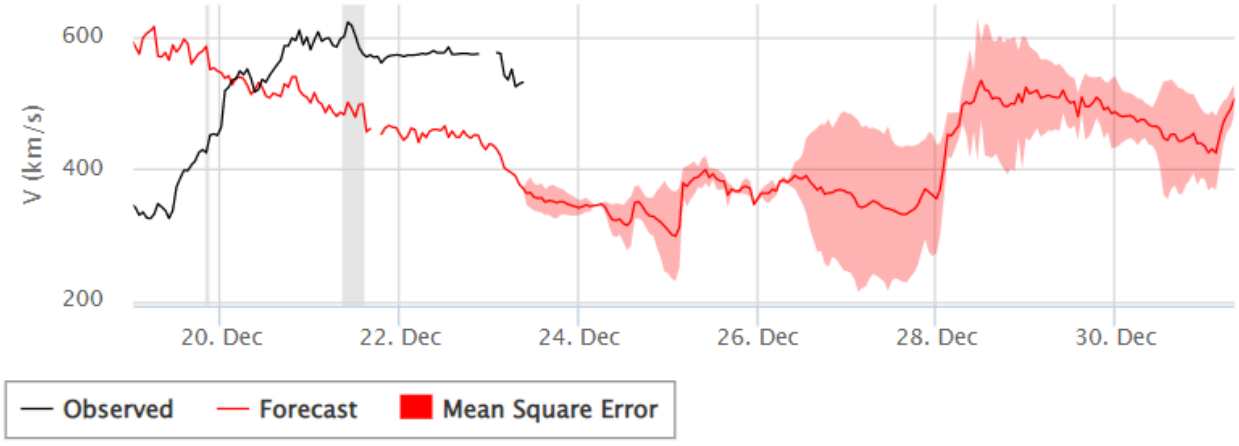


Figure 3: Solar Wind Persistence Model – Currently not a good indicator of conditions, but in the absence of CME arrival, likely to trend towards this value as a background.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.

Radio Blackouts - X-Ray Flares:

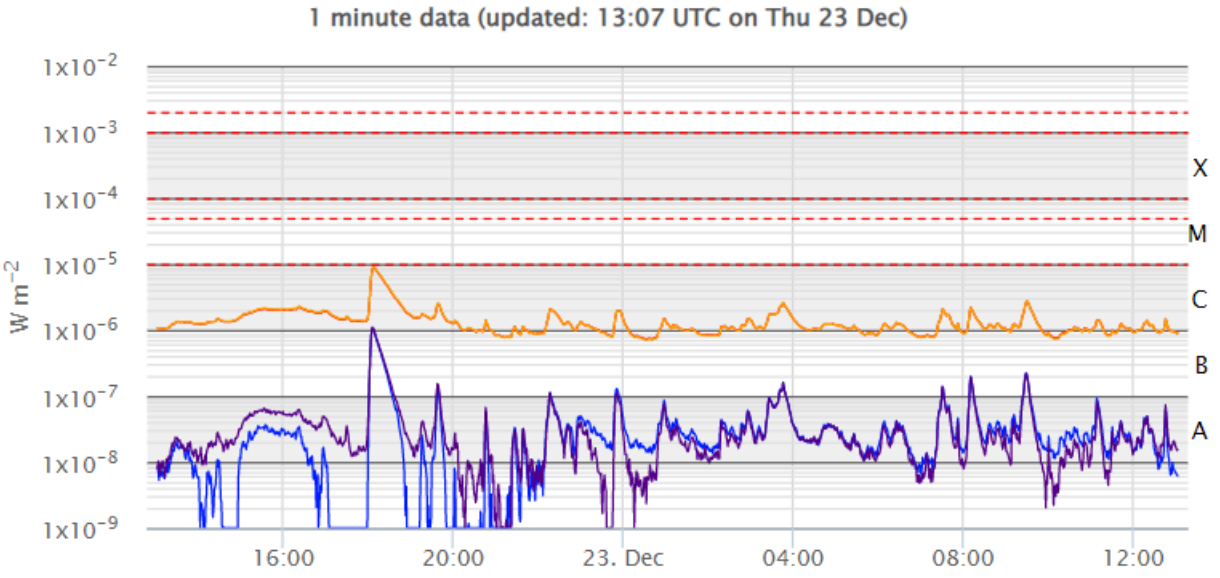
There are currently nine sunspot containing active regions, with Low solar activity

AR2907 Eac/Beta in the southwest has continued to develop numerous intermediate spots and has been the source of recent C-flaring. This spot has been increasing in complexity and will be monitored for notable flares. AR2908 Cai/Beta and AR2909 Hax/alpha have continued their gradual decay since the M-flare from AR2908 on the 22nd. AR2911 Axx/alpha, AR2912 Hrx/alpha and AR2915 Cro/Beta are simpler and largely stable regions. AR2916 Eho/Beta is a simple bipolar region, despite a large leader spot and being the source of an M-flare on the 21st. AR2917 Dai/Beta and AR2918 Dai/Beta are both developing regions in the eastern hemisphere, and a potential source of further flares as they gain complexity.

Solar activity is currently Low, however the ongoing development of AR2907, history of flaring from AR2916 and coupled with new sunspots AR2917 and AR2918 only recently emerging, there is a chance (40%) of M-flares through the period. There is also a slight chance (10%) of low X-class flares, primarily from AR2907.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	40	40	40	40
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: GOES-16/17 X-ray Flux



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

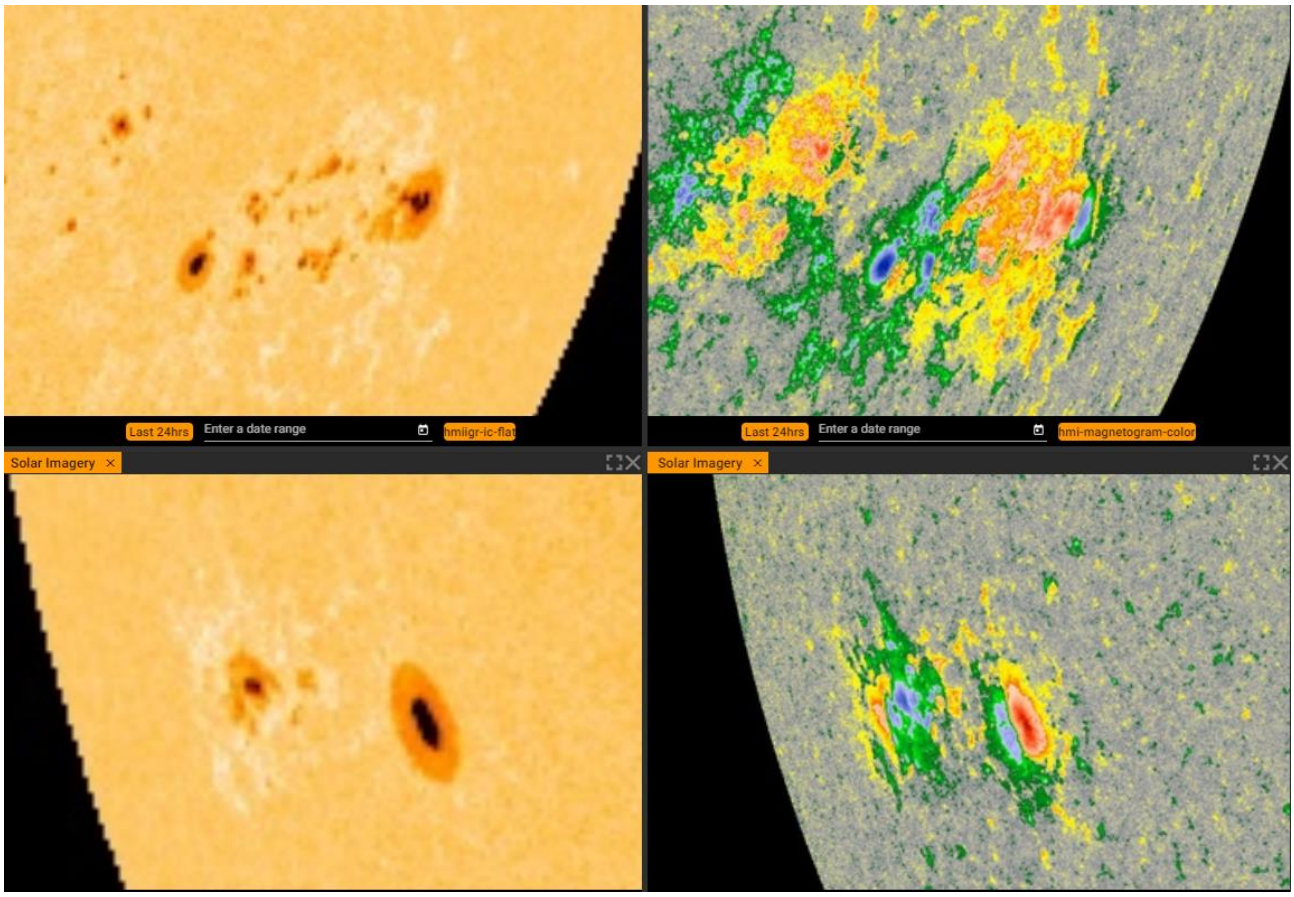
© Crown Copyright 2021. All Rights Reserved.

Solar Radiation Storms - (High Energy Protons):

The high energy proton flux (greater than 10 MeV) as observed by GOES-16 is currently at background levels and expected to persist at these levels. AR2907 is in a geoeffective location for proton storming, should any proton rich eruption occur.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	5	5	5	5
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: SDO HMI-Intesitygram and HMI Magnetogram of AR2907 (Eac/Beta) and AR2916 (Eho/Beta), the largest sunspots on the Earth-facing disc.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.

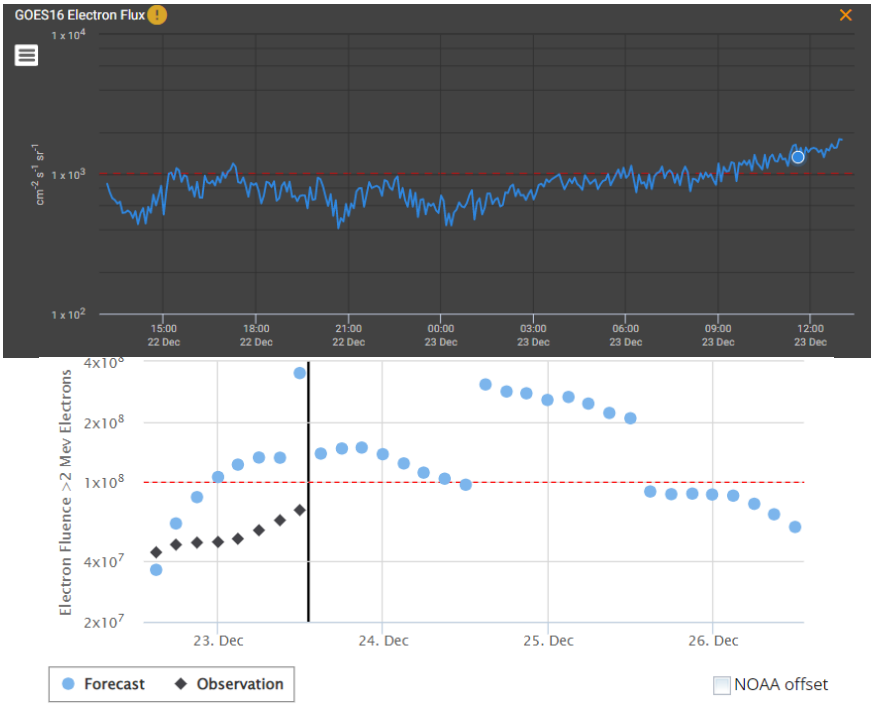
High Energy Electrons Event (≥ 2MeV):

The high energy electron flux (greater than 2MeV) as measured by GOES-16 at GEO has been gradually building day by day, exceeding the high (1e3pfu) threshold on the 23rd, and is expected to continue at this level. This is due to the recent prolonged enhanced solar winds receding, allowing a relaxation of any compression of the Van Allen belts, and subsequently increasing observed flux at GEO. However, increased geomagnetic activity in association with a CME late on day 1 into day 2 (23rd/24th), is likely to lead to a redistribution of electrons within the radiation belts, potentially reducing flux levels, although with low confidence. If the CME arrival is later, or weaker there is the potential for more prolonged High flux to persist.

The associated fluence is likely to rise above the Active threshold day 1 (23rd) before any CME arrival. As this occurs, flux may drop out, however fluence will take longer to respond with Active fluence potentially persisting into day 2 (24th). This is low confidence how, as this depends upon the CME arrival. Due to the CME in the forecast, REFM is only giving good guidance until any arrival occurs. REFM is also over-estimating fluence for T+24 onward.

GEO Electron Environment	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability (Exceedance)			(%)	(%)	(%)	(%)
Active	≥ 2 MeV ≥ $1x10^8$	No	60	60	20	20
Very Active	≥ 2 MeV ≥ $1x10^9$	No	1	1	1	1

Figure 5: GOES-16 >2MeV Electron Flux and fluence with REFM.



Issued by Met Office Space Weather Advisor, Tel: +44 (0) 330 135 4254 Email: moswoc@metoffice.gov.uk

© Crown Copyright 2021. All Rights Reserved.